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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES

In re application of:

Nilو FAGIOLINI et al.

Serial No. 09/423,746

Filed: November 15, 1999

For: REACTIVE POWDER COMPOSITION  
AND METHOD FOR PURIFYING GAS

Art Unit: 1754

Examiner: T. Vanoy

Atty. Docket No. 32232-152197

Customer No.



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**BRIEF ON APPEAL**

Assistant Commissioner for Patents  
Washington, D.C. 22031

Sir:

This BRIEF is filed pursuant to a timely filed Notice of Appeal. The Brief is filed in triplicate.

References relied upon by the applicants during prosecution are attached hereto, including copies of

Kirk Othmer Encyclopedia of Chemical Technology, Fourth Edition, volume 22,

Wiley Interscience Publication, p.276. [1997], including copyright page.

a page of Terence Allen's book entitled "Particle size Measurement", Second Edition, published by Chapman and Hall Ltd.(1975)[Enclosure 1] and

a copy of a page from Ullmann's, Encyclopedia of Industrial Chemistry, Fifth Edition, Vol. A7, p. 160-161, 1986, editor Wolfgang GERHARTZ, publisher:VCH., (Enclosure 2)].

These references were attached to the two responses to the FINAL REJECTION.

### **REAL PARTY IN INTEREST**

The instant application is assigned to SOLVAY S.A.

### **RELATED APPEALS AND INTERFERENCES**

The undersigned is not aware of any appeal or interference which would affect, or be affected by, the outcome of the appeal in this case

### **STATUS OF CLAIMS**

The claims 1-10, 12 and 13 stand finally rejected under 35 U.S.C. §§103 and/or 112 and for obviousness type double patenting.

### **STATUS OF AMENDMENTS**

The initial Rule 116 September 3, 2002 AMENDMENT was denied entry [PTO Paper no. 21]. Resubmission of the amendment with conformance of the 'clean copy' to the 'marked up version' of amendment of Claim 1 therein resulted in entry of the September 18, 2002 Rule 116 AMENDMENT, as set forth in PTO paper no 24. The PTO, however, refused [in Paper No. 27] consideration of a paper entitled "PRESENTATION OF EXCERPT FROM KIRK-OTHMER" filed by applicants on October 1, 2002. A request for reconsideration of that refusal is filed concurrently.

### **SUMMARY OF THE INVENTION**

The invention concerns a solid pulverulent reactive composition based on sodium bicarbonate, for gas purification and scrubbing gases which may contain sulfur oxides and/or hydrogen halides [please see specification at page 1 line 10 et seq.].

The composition comprises sodium  
sodium bicarbonate and  
a caking inhibitor for sodium bicarbonate;

said inhibitor is selected from the group consisting of lignite coke, a magnesium compound and admixtures thereof, wherein said magnesium compound is selected from the group consisting of magnesium oxide, magnesium hydroxide, mixtures of magnesium oxide and magnesium hydroxide and magnesium hydroxycarbonate;

The composition of the claims is said to be devoid of silica. The invention addresses the problem of agglutination of such compositions, the tendency of the sodium bicarbonate to cake). The inventors have discovered that silica content in such compositions negatively affects the gas cleaning process, in particular when the removal of dust is carried out by means of a filter cloth (Please see the specification at p.5, 1. 24-34). The inventors believe that the silica-free compositions adhere better to the filter cloth than the silica-comprising compositions. The reference to filter clothes relates to means used to remove dust, **i.e. solid waste**, from the gases. Please see page 5 line 15 et seq. of the specification relating to dust removal Accordingly, Claims 1, 12 and 13 recite “devoid of silica”.

Moreover, according to a specially recommended embodiment of the invention composition, which adheres well to such filter cloth, the composition is characterized by a fine mean particle size of less than 50 $\mu$ m and a narrow particle size distribution (slope of less than 5) (see description p.3, 1.19 – p.4, 1.4).

Such particle sizes can be obtained by milling commercial sodium bicarbonate (see example 1). Amended claim 1 incorporates the characteristics of particle size: “*said composition exhibiting a mean particle size of less than 50 $\mu$  and a particle size slope of less than*

5." The particular particle sizes of the composition according to new claim 1, in conjunction with the new caking inhibitor and the absence of silica, have proven to be particularly effective, as demonstrated by the examples of the patent application.

Such particle sizes are not those of standard sodium bicarbonate but require additional treatment, for instance milling and sieving, as described in example 1 of the specification at page 8.

## ISSUES

Is Claim 13 unpatentable under 35 U.S.C 112?

Are Claims 1-10, 12 and 13 unpatentable for obviousness type double patenting over Claims 1-14 of U.S. Patent No. 6,171,567 in view of the English translation of DE 41 00 645A1?

Are Claims 1-10 and 12 unpatentable under 35 U.S.C. 103(a) as being unpatentable over German Patent Doc., No. DE 41 00 645 A1 to Regler et al in view of WO 95/19835 to Fagiolini?

## GROUPING OF CLAIMS

Claim 13 is separately patentable from the remaining claims since it is clear from the various grounds of rejection that the art does not pertain to the recitations in Claim 13.

## ARGUMENT

### I. Section 112 rejection of CLAIM 13.

In the Final Action, the reason advanced for the rejection of Claim 13 follows:

"Claim 13 is rejected under 35 U.S.C. 112, first paragraph, as containing subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed

invention. Neither specification on pg. 3 ln. 24 to pg. 4 ln. 4 or in claim 13 explain how  $D_{90}$  can represent the diameter at which 90% of the particles have a diameter less than  $D_{90}$ . It seems that one would have to know what the  $D_{90}$  is on the right side of “represents” in order to determine the  $D_{90}$  on the left side of “represents”. A similar rejection is made for the corresponding  $D_{50}$  and  $D_{10}$  expressions. [Paper No. 17, pages 2-3]

Contrary to the PTO reasons, the expressions are supported, i.e. appear at page 3 lines 19 through page 4 line 4 of the specification; that is, *in haec verbis* support was provided in the U.S. application specification for the expression(s). Specifically, at page 3 line 19 et seq. the specification recites,

In this embodiment of the invention, the mean diameter ( $D_m$ ) and the particle size slope ( $\sigma$ ) are defined by the following relationships:

$$D_m = [\sum n_i \times D_i] / \sum n_i \text{ [sic]}, \quad \sigma = [D_{90} - D_{10}] / D_{50}$$

In which  $n_i$  denotes the frequency (by weight) of the particles of diameter  $D_i$ , and  $D_{90}$  represents the diameter at which 90%... of the particles of the reactive composition... have a diameter of less than  $D_{90}$ ...”[specification, pg. 4]

Moreover, on page 4 of the specification the appellants indicate the conventional means for making the measurement for particle classification.

Thus, on the strictest reading of Section 112, the PTO position appears inapposite, as both the written description requirement and enablement have been provided by the specification. However, to show on the record that the particle size classification was well

within the skill of the art applicants presented various references which speak to particle size classification: Copies of the three references are attached hereto. These references date from 1986, 1975 and 1997.

Those previously submitted references include:

a page of Terence Allen's book entitled "Particle size Measurement", Second Edition, published by Chapman and Hall Ltd.(1975)[Enclosure 1] and

a copy of a page from Ullmann's, Encyclopedia of Industrial Chemistry, Fifth Edition, Vol. A7, p. 160-161, 1986, editor Wolfgang GERHARTZ, publisher:VCH.]

Those two references were attached to the two responses to the FINAL REJECTION. On October 1, 2002 appellants also filed

**Kirk Othmer Encyclopedia of Chemical Technology**, Fourth Edition, volume 22, Wiley Interscience Publication, p.276. [1997], including copyright page.

Better than an Inventor's declaration, this latter excerpt presents a very clear illustration of the "D90" etc concept: At the top of the page, a very clear cumulative graph is presented. To find, say, D90, you select 90 on the "Y" axis and read the corresponding D90 value on the "X" axis (idem for D50 etc.)

The totality of the references suggests the recitations relating to D90 , D50 and D10, would be well within the comprehension of a person of ordinary skill.

**Accordingly, reversal of the rejection under 35 U.S.C. 112 is respectfully solicited.**

## **II. The claims are not obvious under 35 U.S.C. 103(a)**

In Applicants' view, the references commend to the person of Section 103(a) inclusion of a reagent which is expressly eliminated from Claims 1 and 12, from which the remaining claims

depend. [As noted in a previous response, PTO policy as expressed in the MPEP, Section 2111.03, the phrase "consisting essentially of" in e.g. appealed Claim 12 is construed to limit the scope of a claim to the specified materials and "those materials that do not materially affect the basic and novel characteristic(s)" of the claimed invention. In re Herz (citation omitted).] Elimination of an element suggested in the prior art with improved results in an area unsuggested by the prior art is the epitome of non-obviousness. Please see the cases, In re Anthony 64 USPQ 553 at 555-556 (CCPA 1945); In re Miller 94 USPQ 88 (CCPA 1952); In re Fleissner, 121 USPQ270 (CCPA 1959).

Applicants respectfully traverse the rejections of the claims under 35 U.S.C. 103(a) over German Patent No. DE 4100645 (Regler) which discloses a composition for the purification of gas, taken with WO 95/19835. The title of the Regler reference is "*Waste gas purificn. With nitrogen basic cpds. Removing acid cpds. – by adding ammonia and alkali and/or alkaline earth cpds., for foundry, alkali chloride electrolysis, blast furnace, power station, refuse and glass industry.*" In general the Regler composition comprises:

- A basic alkaline and /or alkaline earth substance;
- A basic compound comprising nitrogen for absorption of NO<sub>x</sub>;
- An additive with large specific area, including explicitly silica to absorb certain impurities and improving the reactivity with the gas.

More specifically, the Abstract of the Regler reference recites

"Nitrogen bases (IA) are injected above the dw pt. Of H<sub>2</sub> in addn. to basic alkali and/or alkaline earth cpds. (IB), mixed with the gas stream and reacted and the solids are sepd. In dust separators. Zeolites are used as surfactant (II) together with (IB). Pref. (IA) is NH<sub>3</sub>, ammonium salts, e.g. NH<sub>4</sub>Cl, urea and/or prim.,

sec. and/or tert. Amines, (NH<sub>3</sub> gas) (B) is NaOH, KOH, NAHCO<sub>3</sub>, Na<sub>2</sub>CO<sub>3</sub>, KHCO<sub>3</sub>, K<sub>2</sub>CO<sub>3</sub>, quicklime, Ca(OH)<sub>2</sub>, limestone, MgO, Mg(OH)<sub>2</sub> and/or MgCO<sub>3</sub>, as solid, soln. or suspension. (IB) may be mixed with (II) content of the (IB)/(II) mixt. Is 0.1-95,(0.5-50) esp. 1-10%.”

Applicants respectfully traverse the rejection of Claims 1-10 and 12 under 35 U.S.C. 103(a) as unpatentable over German Patent Doc DE 4100645A1 to Regler [hereinafter ‘Regler’] in view of WO 95/19835.

With respect to the contents of WO 95/19835 [combined with Regler] applicants note that the PTO relies upon it for the English translation of the ABSTRACT. The abstract of this reference suggests that the reactive composition for purifying flue gases comprises sodium bicarbonate and less than 2 wt % of sodium monocarbonate, with a particle size distribution defined by an average particle diameter of less than 0.05mm. Such disclosure does not make up for the deficiencies of Regler with respect to the appealed Claims.

**The differences between Regler and the claims on appeal include the following information:**

- Regler’s invention lies in the addition of *nitrogen containing compounds, in order to reduce the emission of nitrogen oxides*. This is not the object of applicants’ invention to basic alkali and/or alkaline earth compounds; and Regler’s invention is not particularly relevant to the object of the invention, which includes solving an agglutination problem, of sodium bicarbonate. Thus, a man skilled in the art who wants to solve an agglutination problem *would not view the Regler’s paper at all and the PTO has provided no evidence to the contrary!*

- In applicants' invention the bicarbonate is the main active constituent whereas the magnesium compound is a caking inhibitor **additive**. This is emphasized in originally filed claim 3 [now incorporated into claim 1]. To the contrary, in Regler, the alkaline earth compound can be the main or only (and even **preferred**, see the example) active basic constituent for the gas purification.
- Regler's compositions comprise alkali and/or alkaline earth. The selection of sodium bicarbonate **and** a magnesium compound among 6 alkali and 4 alkaline earth (burned lime, calcium hydroxide, calcium carbonate and magnesium compound) amounts to the selection of two elements among a list of 10 elements, that is one among 90 (10 times 9).  
**Moreover, Regler recommends adding a surface active substance, including one which is silica.** The probability **avoiding** silica is 4/5, since silica is in a list of 5 elements. In summary, the reconstitution of the constituents of the invention through multiple selections in the 3 Regler's lists, amounts to a selection of one element in a hundred!
- In order to elicit applicants' invention from Regler, the skilled man would have had, after the selection of one-among a hundred of possibilities, to **modify the proportions** of the selected constituents of the composition. Indeed, in Regler, the magnesium compound is possibly the single candidate of choice as the basic active substance for gas purification. In his only example, Regler discloses a composition consisting of calcium hydroxide only (which is in the same list as the magnesium compounds). By comparison, according to the invention, the magnesium compound is an additive, in proportions of at most 10% in weight!

- The comparison of the applicants' specification examples 7 (in accordance with the invention) and 8 (not in accordance with the invention reveals the particularly interesting advantage of avoiding, according to the invention, the presence of silica. in the reactive composition.
- In conclusion, the Examiner's reasoning is hindsight reconstruction of the Regler invention. The complexity of the selections and modifications needed to reconstitute the claimed subject matter proves that the invention is ***nonobvious*** over Regler.

The PTO selection from the choices provided by Regler requires applicants' own claimed subject matter as the record here does not establish that Regler's description provides express motivation to exclude silica or an expectation of success. To establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. The teaching or suggestion to make the claimed combination and the reasonable expectation of success must both be found in the prior art, not in applicant's disclosure. *In re Vaeck*, 947 F.2d 488, 20 USPQ2d 1438 (Fed. Cir. 1991).

Applicants' composition is non obvious for the following reasons:

1. Applicants' invention is intended to solve an agglutination problem (the composition is a caking inhibitor-see claim 1-). **Regler does not mention nor suggest an agglutination problem.** As a consequence, after reading the DE 4100645 document, a person skilled in the art would not make, among Regler's

numerous compositions, the very particular selection which solves a problem not even mentioned in the document;

2. In order to reconstitute Applicants' invention from DE 4100645 document, a person skilled in the art must operate successive selections
3. Regler's composition can contain silica (silica is explicitly mentioned among the possible compositions), whereas the Applicants have discovered the negative effect of silica for the agglutination problem. Specifically, Applicants' claims recite that the composition is substantially devoid of silica.

**Reversal of the rejection under 35 U.S.C. 103(a) is respectfully solicited.**

**III. The claims are patentable over the “Obviousness-type Double Patenting rejection.**

Applicants respectfully traverse the rejection of claims 1-10, 12 and 13 under the judicially created doctrine of obviousness-type double patenting over claims 1-14 of U.S. patent No. 6171567B1. The question presented by this rejection is: Does citation of the claims of a reference —under 'obviousness type double patenting-- logically pertain to **appealed claims** which **exclude compositions, the use of which**, in accordance with the reference claims, would **infringe the reference claims?**

Applicants' respectfully traverse the obviousness-type double patenting rejection. In applicants' view, the precepts of In re Vogel apply in the instant situation [In re Vogel, 422F2d 438, 164 USPT 619 (CCPA 1970)]; the issue of double patenting present an analysis akin to the determination of infringement, a question of fact. Substantively, applicants note that the discussion above with respect to the non-obviousness of the invention over Regler, also moots the double patenting rejection. In applicants' view combining two references which relate to

inventions different from each other and different from the claims at issue does not provide a prima facie grounds for double patenting. Evidence of this is that the very composition which applicants' expressly seek to exclude from the claims at issue could be used in a way to infringe the claims of the cited patent [6171567B1].

Legally, applicants' note the Studiengessellschaft Kohle mbH v. Northern Petrochemical Co. [ 228 USPQ 837 Fed.Cir. 1986 ] case precedent. In this case, the court held that claims to a product [as claims 1 and 12 in the instant appeal] are not directed to the same invention as claims directed to a process of use, viz., "[B]ecause the two patents claim different statutory classes of subject matter, composition and process, they are not the same invention. Studiengessellschaft Kohle mbH v. Northern Petrochemical Co. [ 228 USPQ 837, at 840]"

In applicants' view combining two references which relate to inventions different from each other and different from the claims at issue does not provide a prima facie grounds for double patenting. Evidence of this is that the very composition which applicants' expressly seek to exclude from the claims at issue could be used in a way to infringe the claims of the cited patent [6171567B1].

## CONCLUSION

**Reversal of the three grounds of rejection appears to be in order.**

Respectfully submitted,



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December 2, 2002

## APPENDIX

### APPENDIX---CLAIMS

*correct* 1. Solid pulverulent reactive composition for the purification of a gas, comprising at least 90% by weight of sodium bicarbonate and a caking inhibitor for sodium bicarbonate and being devoid of silica, said inhibitor comprising lignite coke and/or a magnesium compound selected from the group consisting of magnesium oxide, magnesium hydroxide, mixtures of magnesium oxide and magnesium hydroxide and magnesium hydroxycarbonate, wherein said composition exhibiting a mean particle size of less than 50  $\mu\text{m}$  and a particle size slope of less than 5 and wherein said inhibitor is present in an amount by weight of greater than 0.5% of the weight of sodium bicarbonate.

*correct* 2. (Thrice Amended) The composition according to Claim 1, wherein said magnesium compound is magnesium hydroxycarbonate.

3. The composition according to Claim 1, comprising at least 90% by weight of sodium bicarbonate, and an inhibitor present in an amount by weight of greater than 0.5% of the weight of sodium bicarbonate.

*correct* 4. The composition according to claim 3, wherein the inhibitor comprises a magnesium compound in an amount by weight at least equal to 2% of the weight of sodium bicarbonate.

*correct* 5. The composition according to Claim 3, wherein the inhibitor comprises lignite coke in an amount at least equal to 5% of the weight of sodium bicarbonate.

*error* 6. A process for the purification of a gas, comprising introducing a reactive composition *in accordance with* Claim 1 into *the* gas and subjecting the gas to removal of dust.

*correct* 7. The process according to Claim 6, wherein said subjecting the gas to removal of dust comprises filtrating the gas through a filter cloth.

*correct* 8. The process according to Claim 6, for the purification of a gas from at least one contaminant selected from the group consisting of hydrogen chloride, hydrogen fluoride, sulfur oxides, nitrogen oxides, dioxins and furans.

*correct* 9. (Twice amended) The process according to Claim 7, wherein the reactive composition is that of Claim 2.

10. The process according to Claim 1 wherein said silica is one containing less than 0.48% of silica.

*correct* 12. A non-caking solid pulverulent reactive composition for the purification of a gas containing HC1, HF, sulfur oxide, nitrogen oxide, dioxins, furans, and admixtures thereof, consisting essentially of

sodium bicarbonate and

a caking inhibitor for sodium bicarbonate,

said inhibitor is selected from the group consisting of lignite coke, a magnesium compound and admixtures thereof, wherein said magnesium compound is selected from the group consisting of magnesium oxide, magnesium hydroxide, mixtures of magnesium oxide and magnesium hydroxide, and magnesium hydroxycarbonate;

wherein said composition is devoid of silica.

*et al.* 13. The process of Claim 1 wherein the particle size slope is defined by  $\sigma$ , wherein

$$\sigma = \frac{D_{90} - D_{10}}{D_{50}}$$

wherein  $D_{90}$  represents the diameter at which 90% of the particles of the reactive composition (expressed by weight) have a diameter of less than  $D_{90}$ ;

wherein  $D_{50}$  represents the diameter at which 50% of the particles of the reactive composition (expressed by weight) have a diameter of less than  $D_{50}$ ;   

wherein  $D_{10}$  represents the diameter at which 10% of the particles of the reactive composition (expressed by weight) have a diameter of less than  $D_{10}$ .

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

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Serial No. 09/423,746

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AND METHOD FOR PURIFYING GAS

Art Unit: 1754

Examiner: T. Vanoy

Atty. Docket No. 32232-152197

Customer No.



26694

PATENT TRADEMARK OFFICE

**PRESENTATION OF EXCERPT FROM KIRK-OTHMER**  
**(2<sup>nd</sup> submission)**

Assistant Commissioner for Patents  
Washington, D.C. 22031

Sir:

This paper is filed to present a copy of an excerpt from Kirk Othmer. The paper itself includes below a reiteration of the paper of October 1, 2002. However, this paper is filed in view of the Examiner's refusal to consider the reference in the PTO Paper No 27 with reference and reliance on Rule 97(d), which includes the paragraphs (1) and (2) criteria for rationalizing the date of presentation of reference(s) for the Examiner's consideration. As noted previously [in Applicants' Oct. 1, 2002 paper], the excerpt from Kirk-Othmer were not presented in view of Rules 56, 97-99. The reference was presented to provide factual support for applicants' traversal of the Section 112 rejection. In response to the Examiner's reference to Rule 97(d), Applicants' Belgian representatives have indicated that on or after September 30, 2002, the representatives undertook a search to find references supporting their position concerning the PTO rejections under 35 U.S.C. 112. In the same sense, as Rule 195, the prior PTO refusal to consider the

excerpt of a reference. The reason for referring to fees in applicants' October 1, 2002 is based on the experience that some Examiner's prefer the presentations, in the context of an Information Disclosure Statement.

**Kirk Othmer Encyclopedia of Chemical Technology**, Fourth Edition, volume 22, Wiley Interscience Publication, p.276. [1997], including copyright page.

Better than an Inventor's declaration, this excerpt presents a very clear illustration of the "D90" etc concept: At the top of the page, a very clear cumulative graph is presented. To find, say, D90, you select 90 on the "Y" axis and read the corresponding D90 value on the "X" axis (idem for D50 etc.)

This reference is presented as independent corroboration of the previously submitted references which pertain to the same issue, the Section 112, first paragraph rejection of claim 13.

The previously submitted references pertaining to the Section 112, first paragraph rejection of claim 13 include: a page of Terence Allen's book entitled "Particle size Measurement", Second Edition, published by Chapman and Hall Ltd.(1975)[Enclosure 1] and a copy of a page from Ullmann's, Encyclopedia of Industrial Chemistry, Fifth Edition, Vol. A7, p. 160-161, 1986, editor Wolfgang GERHARTZ, publisher:VCH., (Enclosure 2)]. These references were attached to the two responses to the FINAL REJECTION.

Although applicants do not consider this presentation in the nature of an IDS, but rather in the vein of a factual basis for traversal of the section 112, first paragraph rejection applicants cite all three references on a 1449 form; although it does not appear appropriate to authorize treatment as an IDS, applicants note that if treated as such and if a fee is thus necessary, the Patent Office is authorized to charge Deposit Account 22-0261 the appropriate fee.

Reconsideration and an early allowance are respectfully solicited.

Respectfully submitted,



December 2, 2002

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KIRK-OTHMER

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# ENCYCLOPEDIA OF CHEMICAL TECHNOLOGY

FOURTH EDITION

VOLUME 22

SILICON COMPOUNDS  
TO  
SUCCINIC ACID AND SUCCINIC ANHYDRIDE



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JOHN WILEY & SONS

New York • Chichester • Weinheim • Brisbane • Singapore • Toronto

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**Library of Congress Cataloging-in-Publication Data**

Encyclopedia of chemical technology/executive editor, Jacqueline

1. Kroschwitz; editor, Mary Howe-Grant.—4th ed.  
p. cm.

At head of title: Kirk-Othmer.

“A Wiley-Interscience publication.”

Contents: v. 22, Silicon compounds to succinic acid and succinic anhydride  
ISBN 0471-52691-6 (v. 22)

I. Chemistry, Technical—Encyclopedias. I. Kirk, Raymond E.  
(Raymond Eller), 1890-1957. II. Othmer, Donald F. (Donald  
Frederick), 1904-1995. III. Kroschwitz, Jacqueline I., 1942- .  
IV. Howe-Grant, Mary, 1943- . V. Title: Kirk-Othmer encyclopedia  
of chemical technology.

TP9.E685 1992

91-16789

660.03—dc20

Printed in the United States of America.

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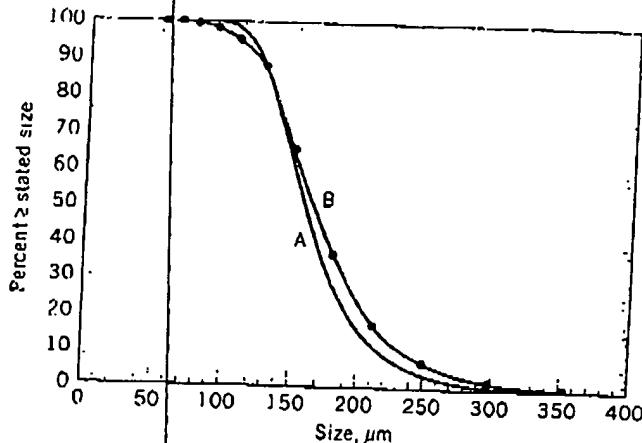


Fig. 15. Size data for a metal powder obtained by A, image analysis, and B, on a diffractometer.

Optical counters have been widely used to monitor cleanroom technology and particles in oil. Instruments manufactured by Royco Inc. (Menlo Park, California) are available for studying aerosols and particles in liquids. The HIAC counter (HIAC Instruments, Monte Claire, California) is a widely used stream counter for particles in fluid. One of the more recently developed optical counters is available from Particle Sizing Systems (Santa Barbara, California). The configuration of one of the widely used counters, the Climet counter, is shown in Figure 16. A general review of photozone counters is available (3).

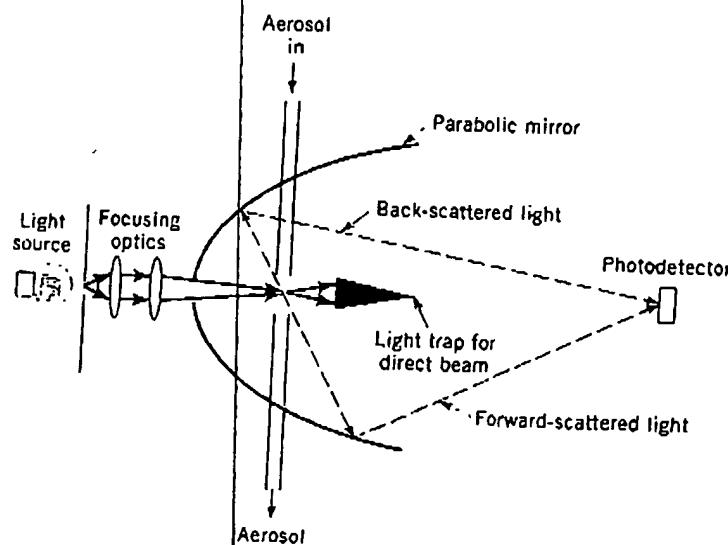


Fig. 16. Schematic representation of the internal structure of a Climet counter.

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Table 4.8 (a) Cumulative percentage undersize distribution

Particle size ( $\mu\text{m}$ )	Interval $x_1$ to $x_2$	$dN$	Average size $x$	Percentage in range $d\phi/dx$	Percentage per micrometre $d\phi/dx$	$\phi = \sum_0^x d\phi$
5	0 to 5	5	2.5	1.4	0.3	0
9	5 to 9	4	7.0	8.0	2.0	1.4
11	9 to 11	2	10.0	8.6	4.3	9.4
14	11 to 14	3	12.5	14.0	4.7	18.0
17	14 to 17	1	15.5	17.5	5.8	32.0
20	17 to 20	3	18.5	14.5	4.8	49.5
23	20 to 23	3	21.5	12.0	4.0	64.0
28	23 to 28	5	25.5	12.0	4.0	76.0
33	28 to 33	5	30.5	12.0	2.4	88.0
37	33 to 37	5	35.0	12.0	1.2	94.0
41	37 to 41	5	39.0	10.0	0.5	98.0
50	41 to 50	9	45.5	14.0	0.2	99.4
60	50 to 60	10	55.0	0.5	0.1	99.9

$\phi$ , the frequency function =  $\sum dN$  for a number distribution

=  $\sum x dN$  for a size distribution

=  $\sum x^2 dN$  for a area distribution

is the percentage of the total number of particles lying in the size range  $x_1$  to  $x_2$ .

Table 4.8 (b) Relative percentage frequency distribution: tabular calculation of mean size

Particle size range $x_1$ to $x_2$	Interval $x_1$ to $x_2$	$dN$	Average size $x$	Percentage in range $d\phi/dx$	Percentage per micrometre $d\phi/dx$	$x d\phi$	$\bar{x} = \sum x d\phi = \sum x \frac{d\phi}{dx} x$
0 to 5	0 to 5	5	2.5	1.4	0.3	0	0
5 to 9	5 to 9	4	7.0	8.0	2.0	1.4	5.6
9 to 11	9 to 11	2	10.0	8.6	4.3	8.6	17.5
11 to 14	11 to 14	3	12.5	14.0	4.7	14.0	27.1
14 to 17	14 to 17	1	15.5	17.5	5.8	17.5	26.8
17 to 20	17 to 20	3	18.5	14.5	4.8	14.5	25.8
20 to 23	20 to 23	3	21.5	12.0	4.0	12.0	20.7
23 to 28	23 to 28	5	25.5	12.0	4.0	12.0	18.7
28 to 33	28 to 33	5	30.5	12.0	2.4	12.0	18.7
33 to 37	33 to 37	5	35.0	12.0	1.2	12.0	18.7
37 to 41	37 to 41	5	39.0	10.0	0.5	10.0	18.7
41 to 50	41 to 50	9	45.5	14.0	0.2	14.0	18.7
50 to 60	50 to 60	10	55.0	0.5	0.1	0.5	18.7

For a weight distribution  $d\phi = x^2 dN$  giving:

$$\bar{x} = \frac{\sum x^4 dN}{\sum x^2 dN} \quad (4.14)$$

The mode and the median may be determined graphically but the above summation has to be carried out for the determination of the mean. However, for slightly skewed distribution, the approximate relationship of the mean, mode, and median holds. For a symmetrical distribution, mode = mean = median. In the illustration, the moments are: mode  $\approx 15.0$ ; median  $\approx 17.2$ ; yielding mean  $\approx 18.2$  (table 4.8).

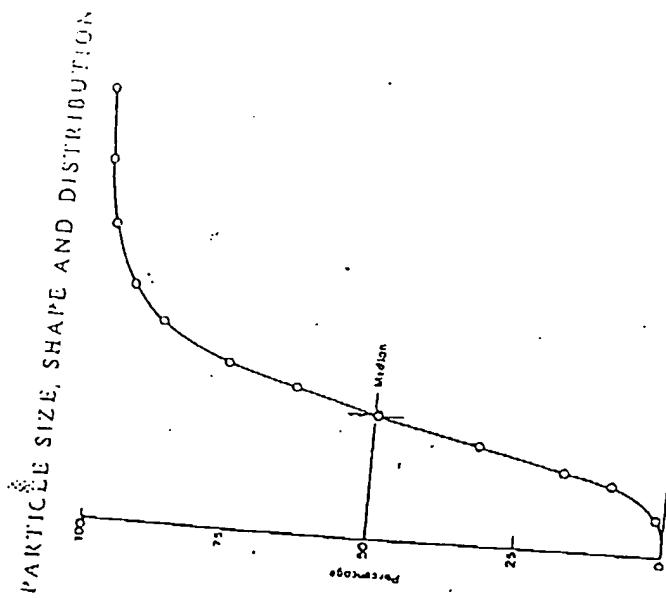


Fig. 4.3. The cumulative percentage frequency curve

passes through the centre of gravity of a slice of a distribution of all the elementary areas of thickness  $\delta x$  about the mean, the moment of the sum of the moments:

$$\bar{x} = \sum x \frac{d\phi}{dx} \delta x = \sum x \frac{d\phi}{dx}$$

$$\bar{x} = \frac{\sum x d\phi}{\sum d\phi}$$

(4.13)

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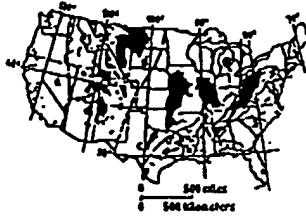
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160 Coal



Figure 1. Geographical location of the world's coal

Figure 2. Coal provinces of the continental United States  
1 Black; 2 Gulf Coast; 3 Northern Great Plains;  
4 Pacific Coast; 5 Rocky Mountains

younger, these coals tend to be of lower rank, usually subbituminous, than the Carboniferous coals. Since the Carboniferous seems coal has been deposited in scattered locations more or less continuously and tends to be lignite or brown coal.

The distribution of coal seems throughout the world is also not uniform. As shown in Figure 1, most of the world's coal is located in only three countries, the United States, the Soviet Union, and China. Although these figures vary from source to source, each of these countries has about 25% of the total coal resources, while the rest of the world shares the remaining 25%. In the United States, bituminous coal seems are concentrated in the Appalachians and Illinois Basin. Most of the subbituminous coal occurs in the various smaller basins in the Rocky Mountain region, and the lignite seems are concentrated in the northern Great Plains and the Gulf Coast area.

#### 4. Classification

Coal is combustible and should be composed of more than 50 wt% carbonaceous material [11]. Commercially, coal is classified in a number of ways on the basis of (1) the original plant or mineral composition, sometimes called coal type; (2) the degree of maturity or metamorphism, called coal rank; (3) the amount of impurities such as ash or sulfur, called coal grade; and (4) the industrial properties such as caking or agglomeration.

One of the main classifications by composition used by the United States Bureau of Mines is based on the relative amounts of four carbonaceous materials depicted in thin-section analysis, including anthracite (undecomposed material roughly equivalent to lignite), subbituminous (roughly equivalent to lignite), and opaque carbon and fusain (roughly equivalent to bituminous) [12, 13]. Under this system, coals are divided into two groups: bituminous, with > 5% anthracite, and subbituminous, with < 5% anthracite. The bituminous coals are subdivided into three types: bright coal, consisting mainly of anthracite and subbituminous carbon with < 20% opaque matter; semiplastic coal, consisting mainly of subbituminous and opaque carbon with 20–30% opaque matter; and plastic coal, consisting mainly of opaque carbon with > 30% opaque matter. The subbituminous coals are divided into several coal, consisting of fusain with opaque, and boghead coal, consisting of fusain with shale.

The various bands or layers in coal evident to the unaided eye have also been classified into five types [14]. Float layers appear bright and shiny; cleats appear as relatively less bright, striated layers; drap is dull and featureless; thin layers are dull gray and thin; charcoal, although these terms (all ending *in situ*) are most specific terms meant to be applied to hand specimen samples, they do have some compositional implications at the microscopical level. For example, vitrain layers contain mainly vitrinite macerals, fusain layers contain mainly fusain macerals, and cleats and drap are estimated to be all three maceral types.

The most important classification for commercial purposes in the United States is the ASTM classification by rank. It is the basis on which most of the coal in the United States is bought and sold. This classification, ASTM Standard D 344 shown in Table 1, divides coal

Vol. A7

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Table 3. Classification of coal by rank<sup>a</sup>

Rank	Group	Fixed carbon min. % (dry, mineral- matter-free basis)	Volatile matter % (dry, min- eral-matter- free basis)	Calorific value min. Duct (moist, mineral-matter- free basis) <sup>b</sup>	Agglomera- tion character
Anthracite	anthracitic subanthracitic subbituminous	≥ 75 72–75 ≤ 72	< 14 < 17 > 17	≥ 32 32–33 ≤ 33	—
Bituminous	bituminous I bituminous II bituminous III bituminous C	≥ 75 ≥ 75 ≥ 75 —	< 16 < 19 < 21 —	≥ 33 33–34 ≤ 34	—
Subbituminous	subbituminous A and subbituminous B and subbituminous C and	— — —	— — —	≥ 14,000 <sup>c</sup> ≥ 13,000 <sup>c</sup> ≥ 12,000 <sup>c</sup> ≥ 11,000 <sup>c</sup>	—
Lignite	Kerite A Kerite B	— —	— —	≥ 11,000 <sup>c</sup> ≤ 10,000 <sup>c</sup>	—

<sup>a</sup>This classification does not include a few such, principally subanthracitic varieties, which have unusual physical and chemical properties and which occur within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain < 1% dry, mineral-matter-free fixed carbon or have > 13,000 Btu/lb moist, mineral-matter-free calorific value.

<sup>b</sup>Moist refers to coal containing its natural inherent moisture but not including volatile water on the surface of the coal.

<sup>c</sup>If agglomeration, classify in low-volatile group of the bituminous class.

Coals having 0% dry, mineral-matter-free water on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of moisture.

It is recognized that there may be nonagglomeration varieties in these groups of the bituminous class, and there are notable exceptions in high-volatile C bituminous group.

into classes, groups, and subgroups. The classes are similar to ASTM groups and based on dry, ash-free volatile matter (p. 260) and moist, ash-free calorific value. The classes are numbered as 0 to 9. The classes are divided into four groups, numbered 0 to 3 on the basis of the swelling properties (free-swelling index (p. 245), also called crackle swelling number, and Rozi index). These groups are further broken down into six subgroups numbered 0–5 on the basis of their Anthracite-Arm classification number and Gray-King coke type. The system is set up in such a way that all coals are classified with a three-digit number, in which the first digit is the class, the second digit is the group, and the third digit is the subgroup.

The lignites and brown coals are only divided into classes and groups. The classes, numbered from 1 to 6, are based on ash-free moisture; the groups, based on dry, ash-free volatile yield, are numbered from 0 to 4. This classification is shown in Table 3 (p. 143).

Although the ASTM and International Systems are different, there is a reasonable corre-